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UHF COPLANAR-SLOT ANTENNA  
FOR AIRCRAFT-TO-SATELLITE  
DATA COMMUNICATIONS

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SUMMARY

A lightweight low drag coplanar-slot antenna has been developed for use on commercial jet aircraft that will provide upper hemisphere coverage in the UHF band at receive frequencies of 468 MHz and transmit frequencies of 402 MHz. The antenna, developed under subcontract to the Government, is part of a program for the development of a system to transmit meteorological data from wide-body jet aircraft to ground users via synchronous meteorological data relay satellites. Antenna of this type are presently being flown on international commercial B747 aircraft on an experimental basis for the National Aeronautics and Space Administration (NASA)/National Oceanic and Atmospheric Administration (NOAA), Aircraft-to-Satellite Data Relay (ASDAR) International World Weather Observation Program.

The low profile antenna (23.5 cm wide by 38.1 cm long by 1.9 cm high) is a conformal antenna utilizing the coplanar-slot approach, developed under NASA subcontract by TRANSO Products, Inc., Venice, California. The coplanar-slot approach is a recent breakthrough in conformal antennas with the advantages over the common stripline antenna of broader frequency bandwidth and improved electrical integrity over wider ranges of temperature. The antenna is circular polarized, has an on axis gain of near +2.5 dB and a HPBW greater than 90°.

1.0 INTRODUCTION

1.1 Need for Weather Data

The United States has been deeply involved in the Global Atmospheric Research Program (GARP) and has assumed responsibility for certain of the activities

which are being coordinated by the National Oceanic and Atmospheric Administration (NOAA). One of the activities is to provide an improved source of meteorological data from aircraft via satellite for long range weather forecasting [1]. The initiative for starting the Aircraft-to-Satellite Data Relay (ASDAR) Program came from a recognition that much of our world's weather originates in the data sparse area of the tropics which are primarily ocean. It was further recognized that these areas are frequently crossed by many of the modern wide-body long-range jet aircraft of the B747, DC-10, and L1011 type. These aircraft contain navigation and air data systems capable of providing the desired weather data, that is, latitude, longitude, wind speed, wind direction, altitude, and outside air temperature. The ASDAR system consists of a data acquisition and control unit to acquire, store and format this data; a clock to time the data sampling and transmission periods; and a transmitter and low-profile upper hemisphere coverage antenna to relay the formatted data via satellite to the National Weather Service (NWS) ground stations as shown in figure 1.

### 1.2 Prototype Installation

A prototype ASDAR system for automatically transmitting this meteorological observation data from aircraft was developed by the NASA Lewis Research Center, Cleveland, Ohio, during 1975-1976. In late 1976 the NASA, on contract to Pan American World Airways (PAA) Inc., installed the ASDAR system on PAA B747 aircraft No. N657PA, with completion of flight testing, Federal Aviation Administration (FAA) approval, and Supplemental Type Certification in February 1977.

### 1.3 Additional Installations

In cooperation with the NOAA, ASDAR systems are installed on several B747 world-wide commercial jet aircraft and on an Air Force C141 airplane (Table 1). These systems are installed and operational on an experimental basis during the GARP time period to provide the National Weather Service (NWS) with the desired additional meteorological data. Data is being relayed from these aircraft to ground receiving weather stations around the world via the U.S. Geostationary Operational Environmental Satellites (GOES series) and the European and Japanese Weather Satellites.

TABLE 1  
ASDAR INSTALLATIONS AND REPORTING TIMES

Airline	Aircraft tail number	Reporting time (min after hr)
Pan Am	PA001Z	02
KLM	KL002Z	04
SAS	SK003Z	06
Qantas	QF004Z	08
Lufthansa	LH005Z	10
Qantas	QF007Z	34
Qantas	QF008Z	36
Qantas	QF009Z	38
Qantas	QF010Z	40
USAF/MAC	US011Z	12/42
Singapore	S0013Z	16
Singapore	S0014Z	44
Singapore	S0015Z	18
British Air	BA016Z	46
British Air	BA017Z	20
South Africa Air	SA018Z	48
South Africa Air	SA019Z	22

The ASDAR data also provides the unique capability in that the transmitted latitude and longitude information automatically provides the exact location of each ASDAR equipped aircraft in real time, and provides an indication of movement of the aircraft versus flight time along the flight route via satellite to ground receiving stations.

#### 1.4 System Performance

Performance of the systems to date has indicated excellent data coverage of aircraft flights from satellite horizon to horizon, indicating that the low-profile coplanar-slot aircraft antenna does provide acceptable hemisphere coverage at two frequencies (468 MHz RX and 402 MHz TX). A sample formatted data printout

message as received and printed by the National Environmental Satellite Service (NESS) is shown in figure 2. The data transmissions are consistently good and free of errors within the coverage area of each satellite. Figure 3 shows data from two U.S. satellites (GOES-1 at 135° W long and GOES-2 at 75° W long). This data is from six aircraft carrying ASDAR over a 1-month period. Sampling of the data occurs every 7.5 minutes (8 times per hr), with transmission of the blocks of stored data once an hour to the satellite. Figure 3 also shows the contour of constant zero degree elevation to the receive satellites as viewed from the aircraft. The data shown are from ASDAR units equipped with internal precision clocks, allowing continuous data collection and hourly transmissions to all satellites within view above the horizon. Earlier model units using the U.S. satellite time reference had somewhat limited performance near the horizon due to the time required for the ASDAR antenna/receiver to lock onto the satellite time signal, start gathering data and then transmit at the next hourly transmission period.

## 2.0 SYSTEM DESCRIPTION

### 2.1 Physical Layout

Figure 4 shows the installation of the ASDAR system in a B747 aircraft. The ASDAR power supply and electronics unit are located in the main electronic equipment area of the lower level of the aircraft. The RF coaxial cable is routed up through the main cabin area to the ceiling of the upper lounge [10.7 m (35 ft)] where it connects to the antenna at station 520. The total system weight including power supply, electronics unit, equipment rack shelves, cabling and antenna is 30.19 kg (66.56 lb).

### 2.2 Data Source

Data inputs to the ASDAR electronics unit are provided from the aircraft's Inertial Navigation Unit (INS) and Air Data System via the Flight Data Acquisition Unit (FDAU). The INS system provides the latitude, longitude, wind direction and wind speed as serial BCD data. The FDAU system provides altitude and outside static air temperature in the form of PCM serial data. Data is stored in the electronics unit and then transmitted to the satellite once an hour. The ASDAR transmitter ON-TIME is nominally 37 seconds during each reporting period (once per hour) during flight, except for ground testing when

the transmitter can be keyed for 2, 4, 8, and 16 transmissions per hour. The ASDAR transmitter output is 80 watts, with approximately 60 watts input at the antenna after coax losses.

### 2.3 System Components

The major units of the ASDAR system are shown in figure 5; the power supply, the coplanar-slot antenna and the electronics unit. The power supply and electronics unit were designed and fabricated by the Lewis Research Center and packaged in standard airline radio-rack units. The antenna was developed under contract by TRANSCO Products Inc., Venice, California, and is packaged in an aluminum casting 23.5 cm (9.25 in.) by 38.1 cm (15.0 in.) by 1.9 cm (0.72 in.) thick. The casting is contoured on the underside to fit the aircraft fuselage. The antenna, along with its 0.32 cm (0.125 in.) silicon rubber pressure-seal gasket weighs 3.12 kg (6.88 lb). Figure 6 shows the antenna mounted on the top side of the B474 "hump" at station 520. The only modifications to the aircraft fuselage for mounting the antenna is the installation of a 0.16 cm (0.063 in.) antenna doubler plate, drill one 2.7 cm (1.063 in.) hole for the RF connector feed-through, and eighteen (18) bolt holes for mounting the antenna to the aircraft.

## 3.0 ANTENNA

### 3.1 Selection of Candidate Antennas

During development of the ASDAR hardware components, a survey of available aircraft antenna types indicated that no existing antenna would meet the requirements for upper hemisphere coverage and flight qualification for use on commercial jet aircraft. Under a joint NASA/PAA effort with TRANSCO Products Inc., a low-profile, lightweight coplanar-slot antenna was developed, fabricated, and tested that would operate over both the 402 and 468 MHz frequency bands and also would meet the requirements for upper hemisphere coverage and FAA flight qualification. Environmental qualifications as required per Radio Technical Commission for Aeronautics (RTCA) Document DO-160 and Boeing Aircraft Company (BAC) Document D6-16050 were completed by TRANSCO. Flight qualification and FAA approval and certification was completed by PAA under the NASA contract. Table 2 shows the finalized specifications that were submitted for the production model antennas.

TABLE 2  
ASDAR ANTENNA SPECIFICATIONS

Frequency	401.7 - 402.1 MHz TX 468.8 - 468.9 MHz RX
Impedance	50 ohm
VSWR	1.5:1 maximum
RF power	90 watts maximum for 37 seconds Maximum duty cycle 37 seconds/3.75 minutes
Axial ratio	5.5 dB maximum (at zenith)
Gain (nominal)	+1.5 dBi (at zenith)
Beamwidth (3 dB)	90°
Polarization	Right hand circular
RF connector	Type N female

### 3.2 Physical Characteristics

The physical characteristics of the TRANSCO antenna are summarized in table 3.

TABLE 3  
TRANSCO PRODUCTS INC. ASDAR ANTENNA

Model number	213F00100-1
Type	Coplanar slot
Size	23.5 cm (9.25 in.) wide 38.1 cm (15.0 in.) long 1.83 cm (0.72 in.) thick
Weight	3.12 kg (6.88 lb) antenna 0.254 kg (0.56 lb) gasket
Gasket material	0.318 cm (0.125 in.) silicon rubber
Mounting screws	18 each type NAS514P1032-20P

The microcircuit element of the antenna is approximately 20.32 cm (8 in.) by 20.32 cm (8 in.) by 1.27 cm (0.5 in.) thick and is fitted into a milled out cavity in the larger aluminum casting (fig. 7). The casting provides the structure for mounting the antenna to the aircraft, serves as a pressure plate

around the RF connector feed-through, provides an aerodynamic fairing on the aircraft contoured surface and protects the antenna element from weather erosion.

### 3.3 Antenna Design Considerations

Because of the requirement for low-profile, lightweight and low-cost antennas that could be installed on commercial jet aircraft with minimum rework to the aircraft structure, the large cavity-backed antennas, cross-dipoles and dipole-over-blade antenna types were ruled out. The large protruding antennas were also ruled out since they would create a weight and drag penalty that would not be acceptable to the airlines for carriage over long periods of time. It was also requested by the airlines that a single, dual-frequency type antenna be used in order to minimize the structural rework required to the aircraft. Therefore, the simpler conformal type narrow-band microstrip radiating patch, where two separate antennas would be required, was considered as a secondary approach. Early investigations had indicated that wide band frequency operation would be difficult to achieve with the patch antenna since the input impedance varies rapidly with frequency and temperature changes [2]. Because of the extreme temperature variations due to altitude changes, frequency shift of the ASDAR signal during flight from Doppler shift, and frequency drift of the transmitter output over extended periods of time, verification of operation with the patch antenna would have required extensive development and testing efforts.

### 3.4 Antenna Construction

The coplanar-slot antenna selected for the ASDAR system is of a multilayer construction as shown in figure 7. The Type N RF connector is mounted on the lower side of the element cavity. The RF connector is mated to a double-stub tuned stripline feed circuit board through a four-port quadrature hybrid. The top insulator board and top ground plane for the feed circuit board also provides the structural assembly (pressure plate) for maintaining overall impedance tolerances and frequency stability. The circuit tuning stubs are pretuned both capacitively and inductively such that they reactively tune the antenna prior to final assembly, eliminating the need for further tuning after assembly and encapsulation is completed. The polycarbonate dielectric material provides the cavity loading, where the dielectric constant uniformity and fabrication

tolerance reproducibility has a significant impact on the antenna performance as to power amplification and bandwidth. The radiating patch over the dielectric cavity is fed by two orthogonally located connector posts to provide the desired circular polarized radiation pattern.

### 3.5 Antenna Operation

The operational description of the antenna, when considered as a transmitter, is as follows (see fig. 7) [3]: The RF energy is fed into the Type N RF connector Section C-C which transforms the feed from coax to stripline. The stripline input is fed to a 90° hybrid. The feed lines presented to the hybrid output are matched using double stub stripline techniques to a VSWR value of 2:1 or less. The feed lines are again transformed from stripline to coax at the antenna dual feed points by use of IPC connectors, shown in Section A-A. The radiating patch is fed through this arrangement at symmetrical points with a quadrature signal, thus producing circular polarization.

The presenting of a 2:1 or less VSWR at the output of the hybrid allows the isolated port to be terminated in a reactive load versus a resistive load. This method prevents excessive power being distributed in the load if the antenna resonant frequency should slightly change.

### 3.6 Antenna Qualifications

On completion of assembly, the antenna is encapsulated to inhibit corrosion and is then painted with an outer protective coating of white aircraft-radome ASTRACOAT material. Qualification tests were completed in conformance with airline required specifications per RTCA DO-160 and BAC D6-16050. Input impedance (VSWR) tests were measured at the center frequencies of 401.9 and 468.8 MHz for the operating frequency ranges of 401.7 to 402.9 MHz (transmit) and 468.8 to 468.9 MHz (receive). Radiation distribution plots of the upper hemisphere were made at 2° increments in azimuth and elevation at the center of the transmit and receive frequency bands. Data was taken with the test unit mounted on a large ground plane simulating the installation area on the B747 aircraft. The values were generally uniformly distributed and without deep nulls (figs. 8 and 9).

Polar plots were made at 15° increments in the vertical plane ( $\phi = 0$  to  $180^\circ$ ) for azimuths of  $\theta = 0$  to  $360^\circ$  at the center of the transmit and receive

frequencies. Conic sections were made in planes parallel to the horizon for 0° through 90° elevation in increments of 5°. The gain of the test antenna relative to a  $\lambda/4$  stub antenna was +2.5 dBci (401.9 MHz TX) and 1.0 dBci (468.8 MHz RX) at the peak of the elevation beam. A lower gain at the receive frequency was accepted in order to achieve (favor) a higher gain in the transmit mode. The gain at  $\pm 45^\circ$  was near 0 dB at each of the two frequencies. The axial ratio was within the 5.5 dB specification at zenith for both frequencies. The temperature and altitude test consisted of a low temperature test at -55° C, a high temperature test at +85° C and an altitude test at the equivalent of 50 000 feet. The power handling capability of the test antenna was measured prior to and during each test by applying 90 watts CW at 401.9 MHz. VSWR measurements were made at each condition, with test results indicating normal operation. Humidity and sinusoidal vibration tests were conducted in accordance with the specified RTCA test requirements. The only exception was minor paint blistering that occurred at high temperature, which was not considered critical.

#### 4.0 CONCLUSIONS

The coplanar-slot antenna developed by TRANSCO Products, Inc. for use on commercial aircraft has operationally demonstrated that a lightweight low-profile conformal antenna can provide consistent and reliable upper hemisphere coverage for data communications between aircraft and satellites. These prototype antenna (and ASDAR systems) have now been operational on B747 international aircraft for over 2 years with a minimum of failures. A few early antennas had experienced increasing VSWR's with time, due to moisture seepage into the cavity area around the antenna mounting screws. This condition was corrected by an improved method of sealing the cavity by TRANSCO, and by sealing around the antenna and its mounting screws during installation on the aircraft. One other antenna had been replaced as a precautionary measure during aircraft overhaul because of hairline surface cracks and leading edge erosion in the protective paint. These problem areas were corrected, and operation to date indicates highly satisfactory performance from these antenna systems.

Because of the successful performance of these prototype systems, the NOAA is now reviewing the desirability and feasibility of making ASDAR a worldwide operational system. To accomplish this effort, the electronics units would be

repackaged for improved reliability and ease of maintenance, and the antenna design would be reviewed for improved performance and lighter packaging to be more compatible for installation on other types of aircraft.

#### 5.0 REFERENCES

1. Bagwell, J. W., and Lindow, B. G., An Airborne Meteorological Data Collection System Using Satellite Relay (ASDAR), NASA Lewis Research Center Technical Memorandum 78992, November 1978.
2. Derneryd, Anders G., Microstrip Disc Antenna Covers Multiple Frequencies, Microwave Journal, Vol. 21, May 1978, pp. 77-79.
3. Greiser, John W., Coplanar Stripline Antenna, Microwave Journal, Vol. 19, October 1976, pp. 47-49.
4. Myhre, R. W., Microstrip Antenna for Aircraft Applications, Interservice Antenna Group Workshop, Point Mugu, California, February 1979.

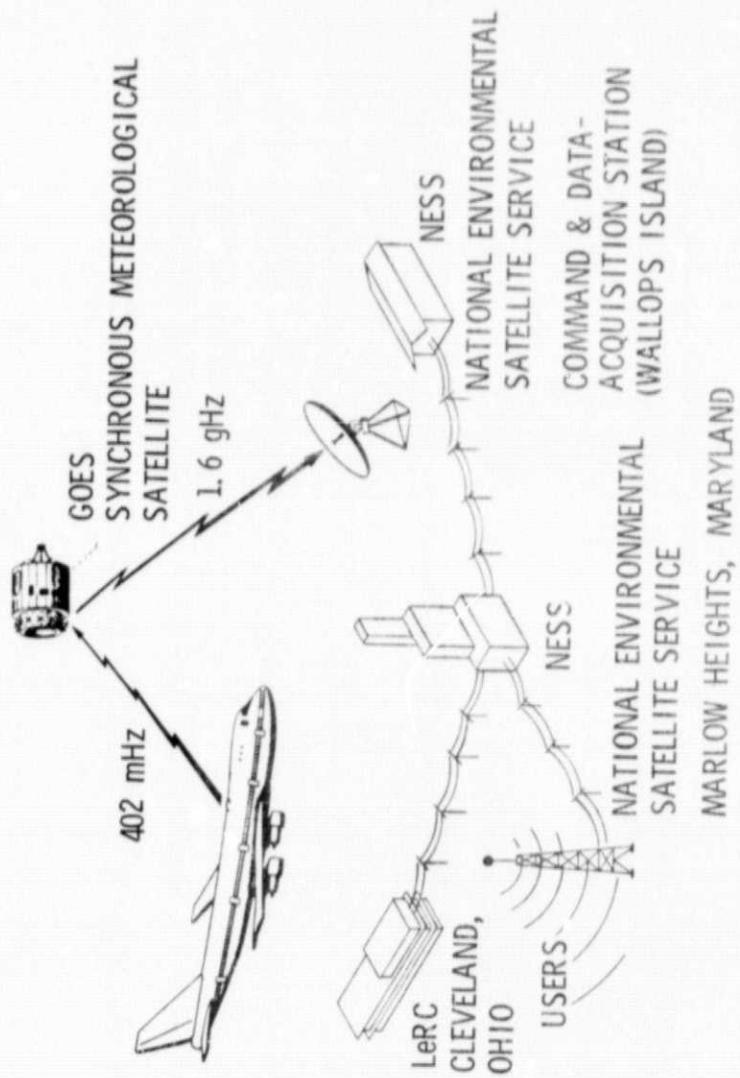


Figure 1. - ASDAR - global weather data gathering system

ASDAR  
 ADDRESS  
 CODE

DATE/IME  
 STAMP WHEN  
 TRANSMISSION  
 RECEIVED

48TH DAY

LATEST DATA -  
 PRINTED FIRST  
 AS DENOTED BY

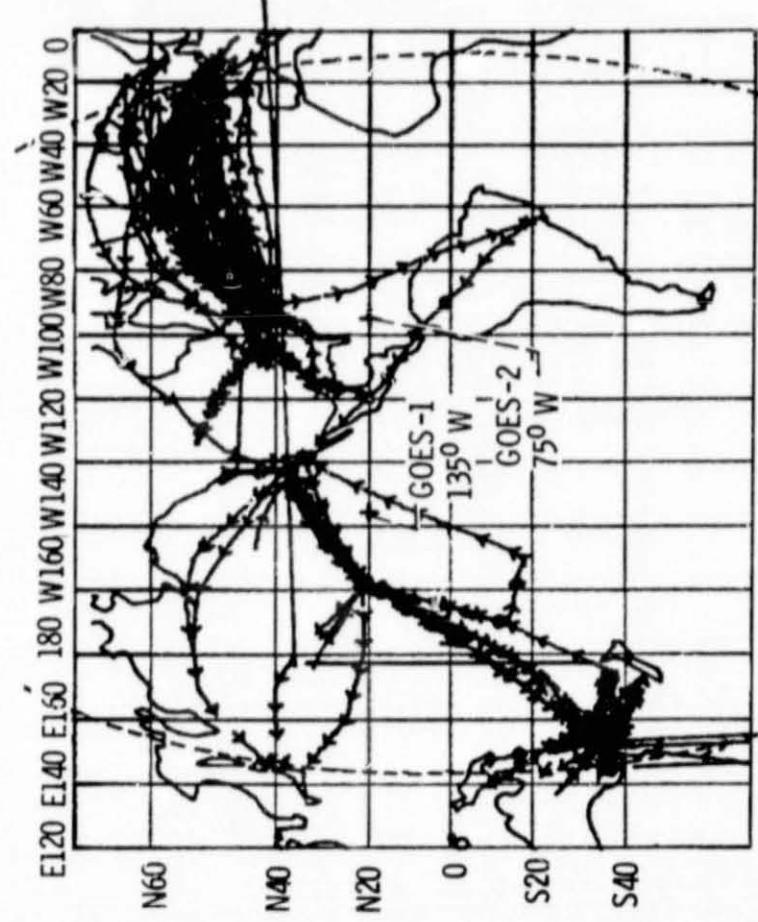
TIME SEQUENCE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
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Figure 2 - ASDAR printout obtained, via satellite relay,  
from National Satellite Service

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ASDAR DATA FROM 01/19/79 TO 02/28/79  
ASDAR PLATFORM ID= A0007022



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Figure 3. - Aircraft ASDAR flight data record with contour of zero degree elevation to U. S. satellites.

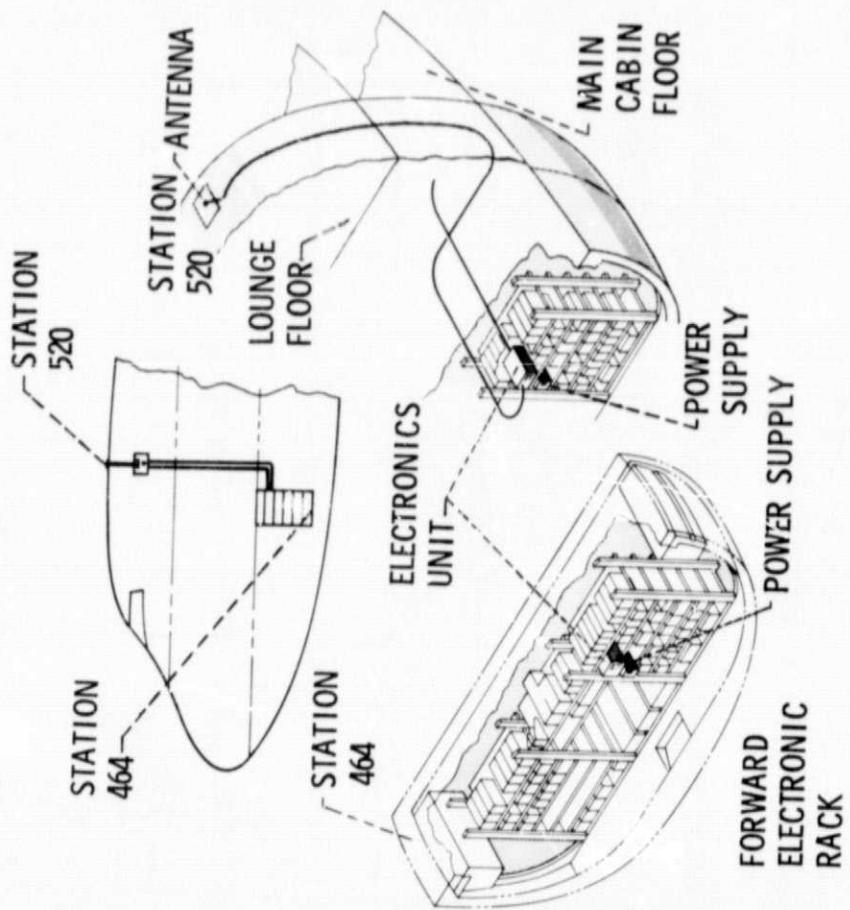
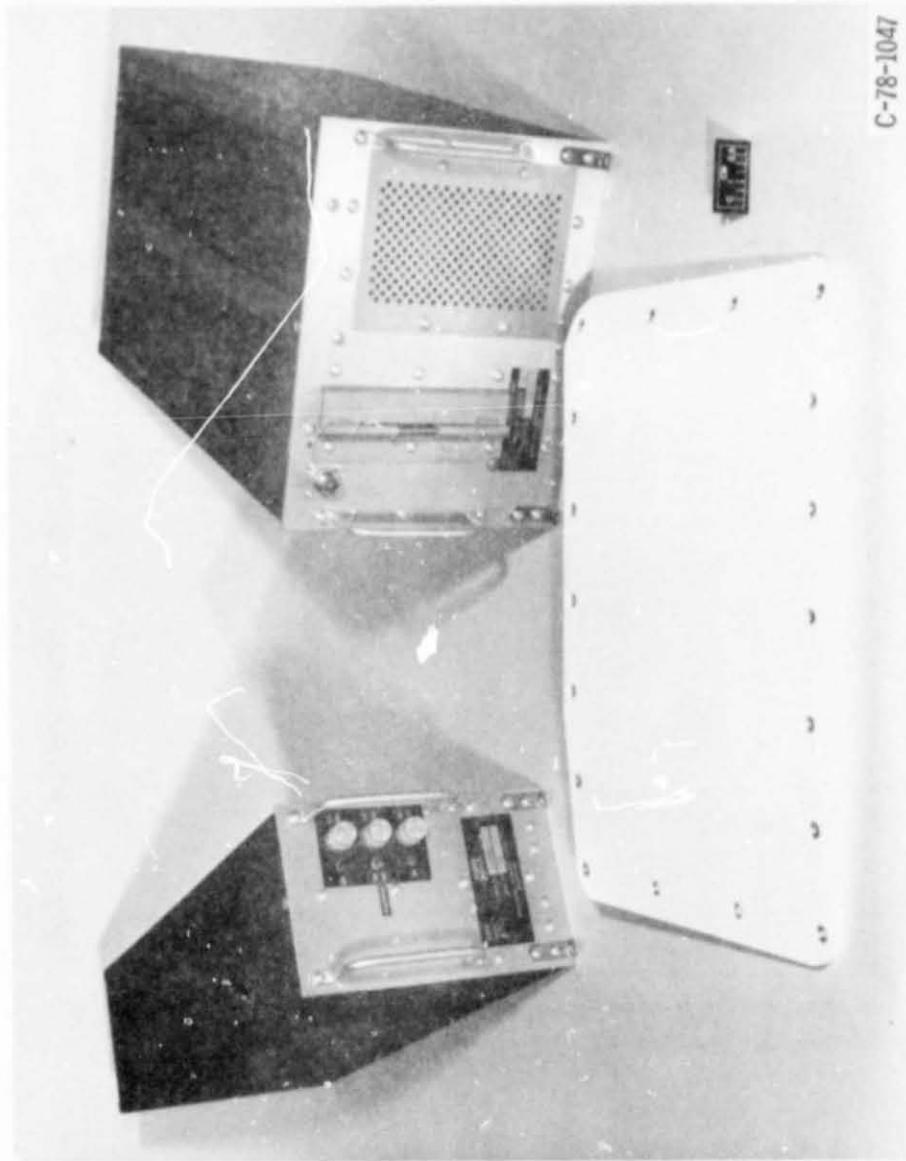


Figure 4. - B747 ASDAR system installation.

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C-78-1047

Figure 5. - A SDAR power supply antenna, and electronics unit.

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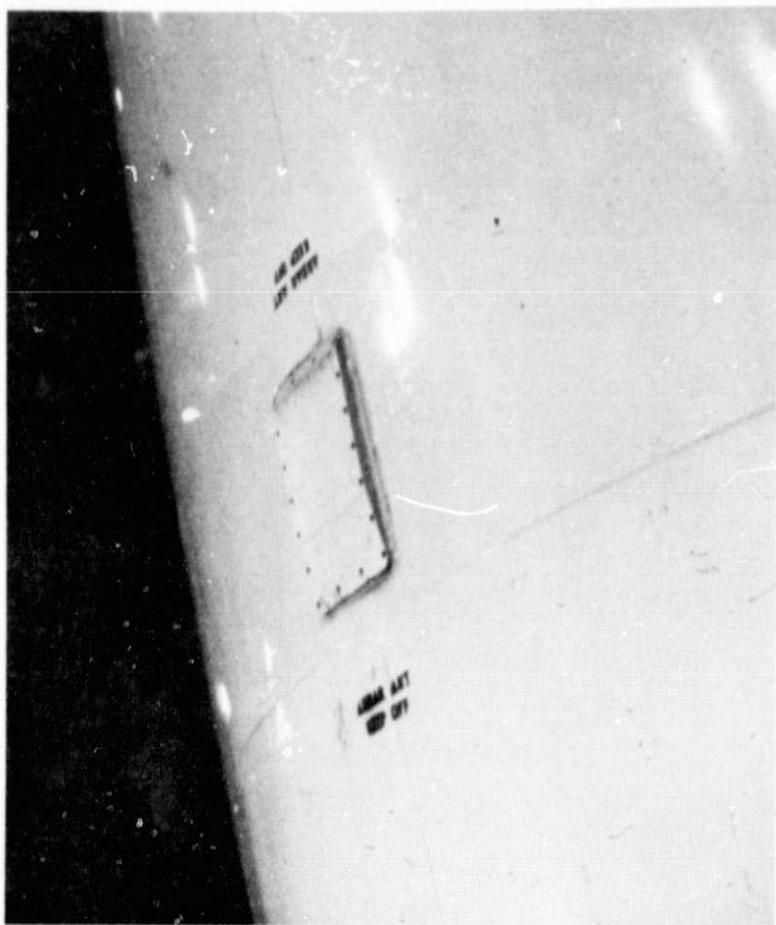


Figure 6. - ASDAR antenna installed on B747 aircraft.

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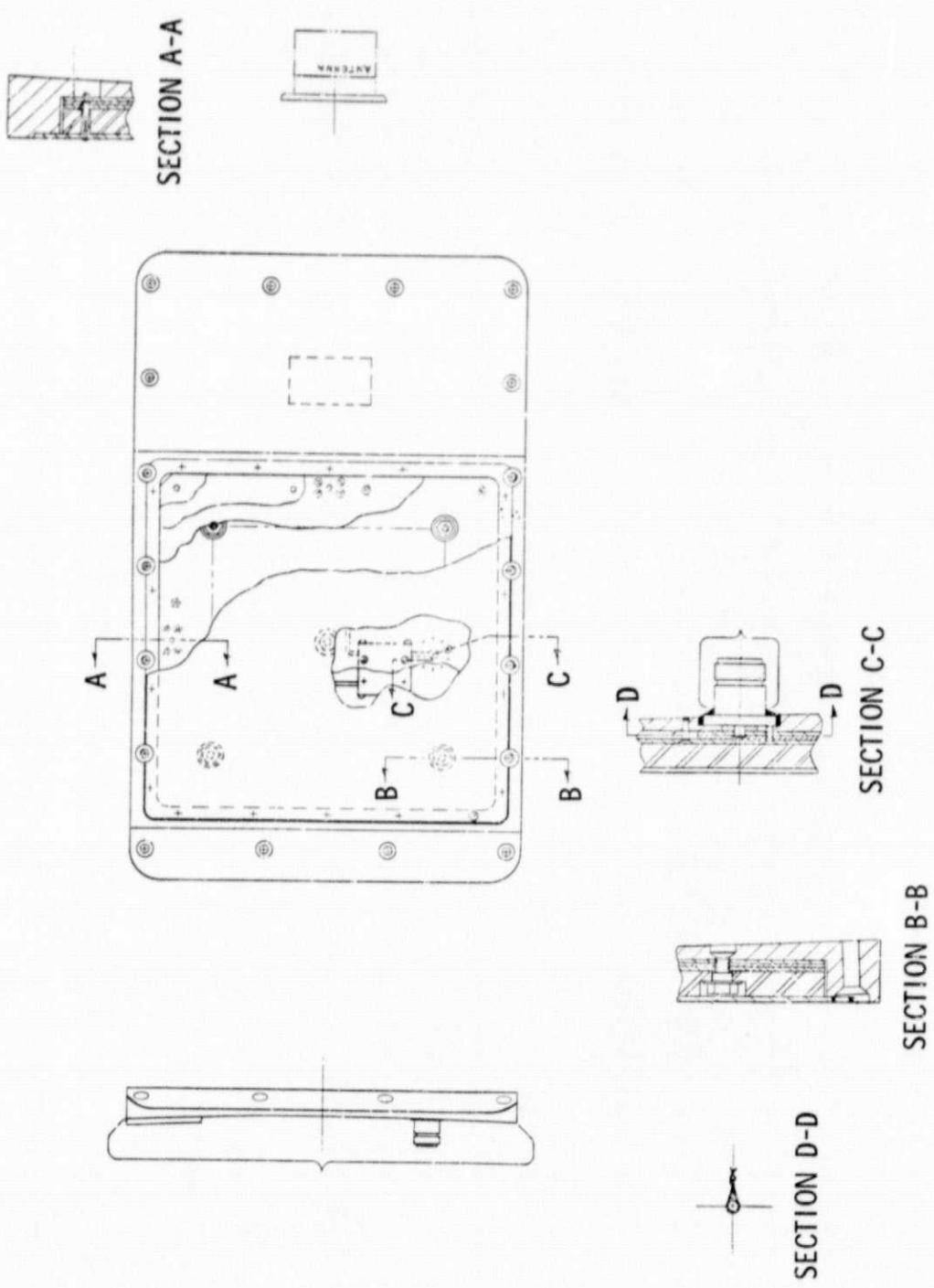


Figure 7. - Transco Products Inc. ASDAR antenna model 213F00100.

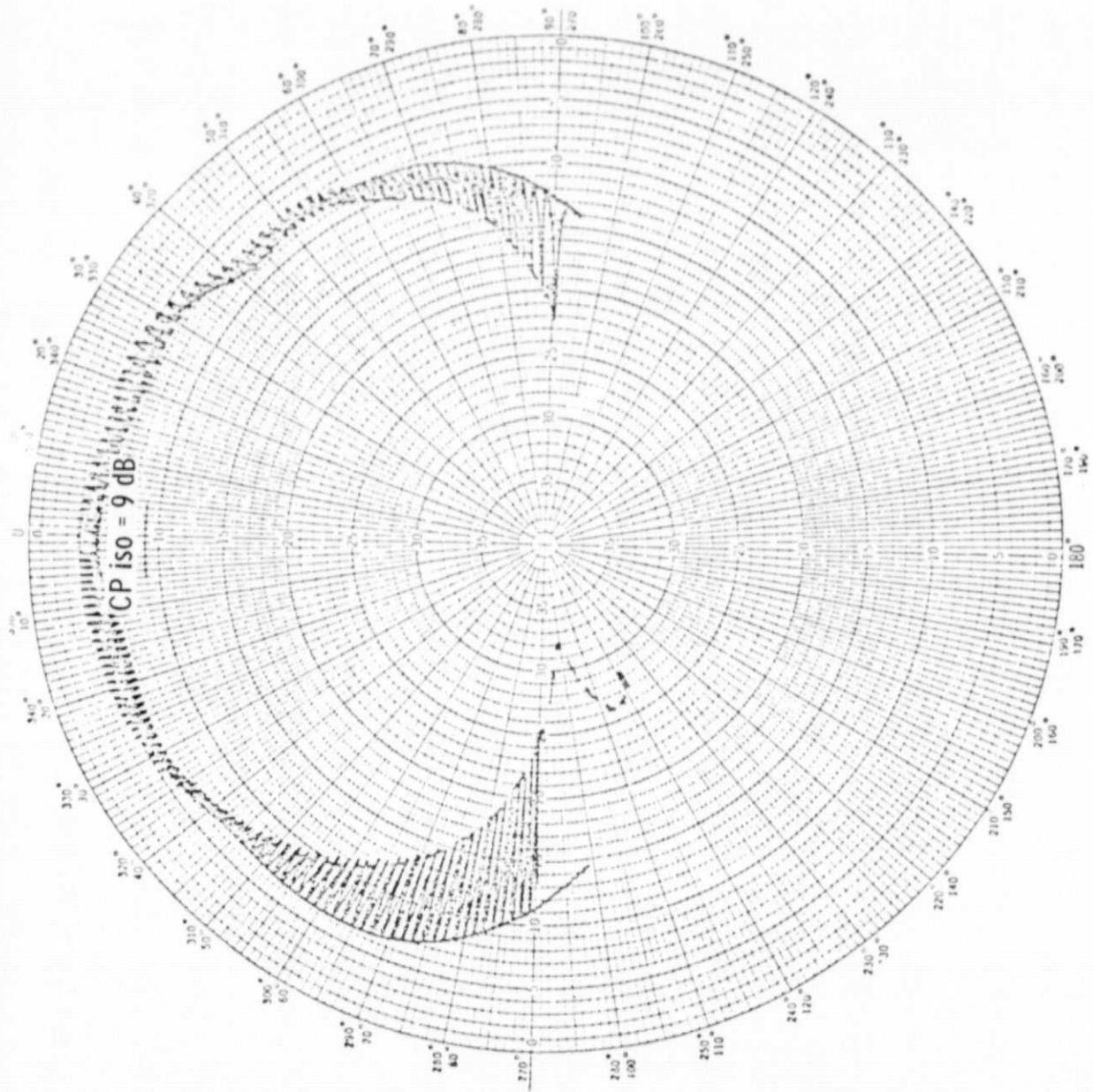


Figure 8. - ASDAR antenna radiation pattern Transco Products model 213F00100, S/N 11; ground plane mockup; freq. 401.9 MHz; aircraft pattern; roll plane.

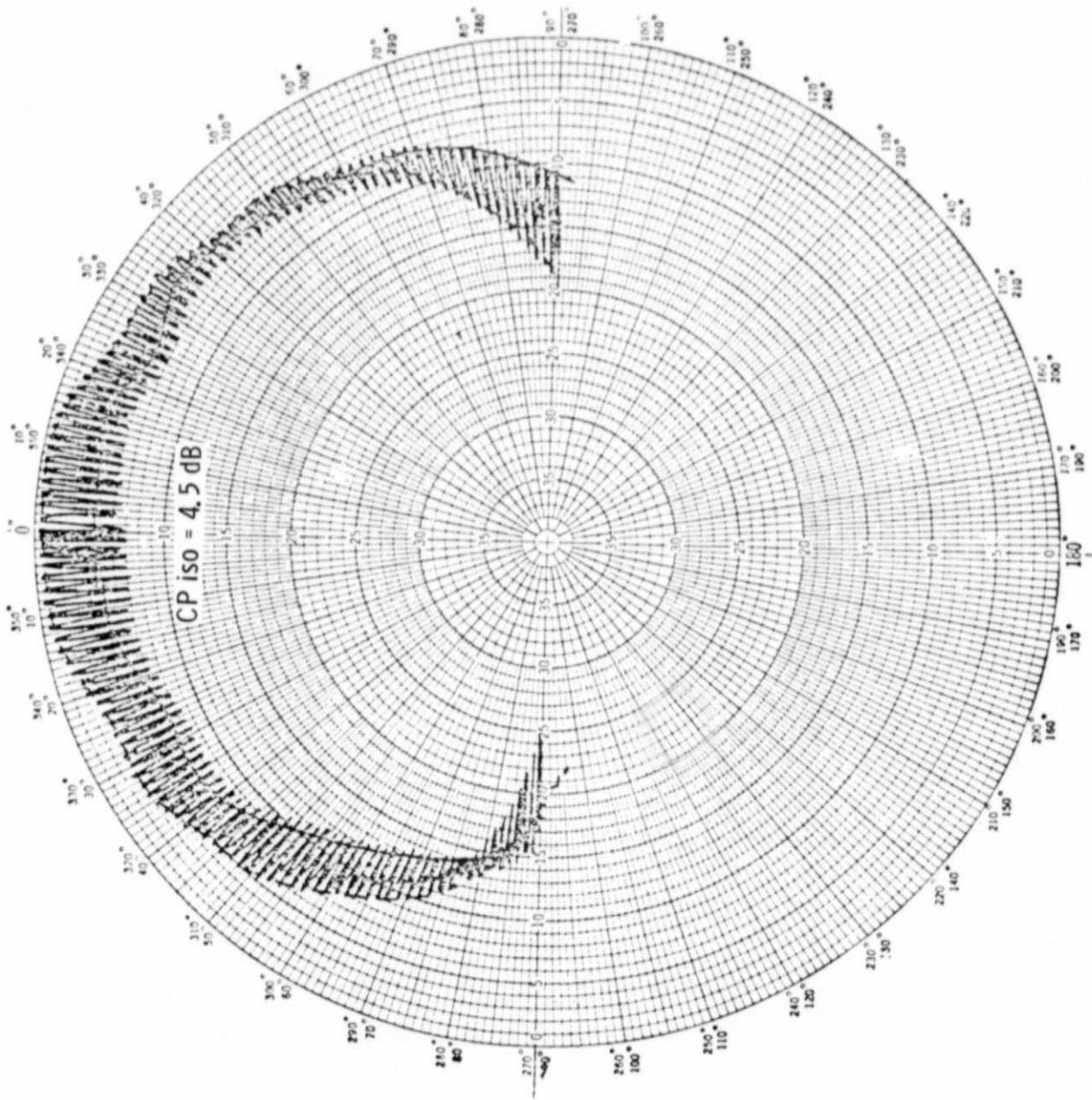


Figure 9. - ASDAR antenna radiation pattern Transco Products model 213F00100; S/N 11; ground plane mockup; freq. 468.85 MHz; aircraft pattern; roll plane.